What is claimed is:

1. Apparatus for use in a mobile user unit in an orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system comprising:

a receiver for receiving one or more pilot tone hopping sequences each including pilot tones, said pilot tones each being generated at a prescribed frequency and time instants in a prescribed time-frequency grid; and

a detector, responsive to said one or more received pilot tone hopping sequences, for detecting the received pilot tone hopping sequence having strongest power.

2. The invention as defined in claim 1 wherein each of said one or more pilot tone hopping sequences is a Latin Squares based pilot tone hopping sequence.

3. The invention as defined in claim 1 wherein said receiver yields a baseband version of a received signal and further including a unit for generating a fast Fourier transform version of said baseband signal, and wherein said detector is supplied with said fast Fourier transform version of said baseband signal to determine a received pilot tone sequence having the strongest power.

4. The invention as defined in claim 3 wherein said receiver further includes a quantizer for quantizing the results of said fast Fourier transform.

5. The invention as defined in claim 3 wherein said detector is a maximum energy detector.

6. The invention as defined in claim 5 wherein said maximum energy detector determines a slope and initial frequency shift of pilot tones in a detected pilot tone hopping sequence having the strongest power.

7. The invention as defined in claim 6 wherein said maximum energy detector includes a slope-shift accumulator for accumulating energy along each possible slope and initial frequency shift of said one or more received pilot tone hopping sequences and generating an accumulated energy signal, a frequency shift accumulator supplied with said accumulated energy signal for accumulating energy along pilot frequency shifts of said one or more received pilot tone hopping sequences, and a maximum detector supplied with an output from said frequency shift accumulator for estimating a slope and

initial frequency shift of the strongest received pilot tone hopping sequence as a slope and initial frequency shift corresponding to he strongest accumulated energy.

8. The invention as defined in claim 7 wherein said accumulated energy is represented by the signal $J_0(s,b_0)$, where $J_0(s,b_0) = \sum_{t=0}^{N_{sy}-1} | Y(t, st + b_0 (\mathrm{mod}\, N)) |^2$, and s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal, *Y(t,n)* is the fast Fourier transform data, $t = 0, \ldots, N_{sy} - 1$, $n = st + b_0 (\mathrm{mod}\ N)$, and $n = 0, \ldots N\text{-}1$.

9. The invention as defined in claim 7 wherein said frequency shift accumulator accumulates energy along pilot frequency shifts of said one or more received pilot tone hopping sequences in accordance with $J(s,b_0) = \sum_{j=1}^{N_p} J_0(s, b_0 + n_j)$, where s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal and n_j are frequency offsets.

10. The invention as defined in claim 7 wherein said maximum detector estimates said slope and initial frequency shift of the strongest received pilot tone hopping sequence in accordance with $\hat{s}, \hat{b}_0 = \arg\max_{s, b_0} J(s, b_0)$, where $\hat{s}$ is the estimate of the slope, $\hat{b}_0$ is the estimate of the initial frequency shift, and where the maximum is taken over $s \in S$ and $b_0 = 0, \ldots, N-1$.

11. The invention as defined in claim 6 wherein said maximum energy detector includes a frequency shift detector for estimating at a given time frequency shift of the received pilot tone hopping sequence having strongest energy and an estimated maximum energy value, and a slope and frequency shift solver, responsive to said estimated frequency shift and said estimated maximum energy value, for generating estimates of an estimated slope and an estimated initial frequency shift of the strongest received pilot signal.

12. The invention as defined in claim 11 wherein said estimated frequency shift at time t is obtained in accordance with $n(t) = st + b_0 (\mathrm{mod}\ N)$, where s is the pilot signal slope, t is a symbol time and *n(t)* is a frequency shift estimate.

13. The invention as defined in claim 12 wherein said estimated maximum energy value is obtained in accordance with $[E(t),n(t)] = \max_{n} \sum_{j=1}^{N_p} | Y(t, n + n_j (\mathrm{mod}\, N)) |^2$, where $E(t)$ is the maximum energy value, $Y(t,n)$ is the fast Fourier transform data, $j = 1, \dots, N_p$ and n_j are frequency offsets.

14. The invention as defined in claim 13 wherein said slope is estimated in accordance with $\hat{s} = \arg\max_{s \in S} \sum_{t=1}^{N_{sy}-1} E(t)\mathbf{1}_{\{n(t)-n(t-1)=s\}}$, where both $n(t)$ *and* $n(t\text{-}1)$ satisfy $n(t) = st + b_0 (\mathrm{mod}\, N)$.

15. The invention as defined in claim 13 wherein said frequency shift is estimated in accordance with $\hat{b}_0 = \arg \max_{b_0 = 0, \dots, N-1} \sum_{t=0}^{N_{sy}-1} E(t)\mathbf{1}_{\{n(t)=st+b_0\}}$.

16. The invention as defined in claim 11 wherein said maximum energy detector detects said slope in accordance with determining the time, $t_0 \in T$, and slope, $s_0 \in S$, such that the set of times t on the line $n(t) = n(t_0) + s_0(t - t_0)$, has the largest total pilot signal energy.

A3 Int

17. A method for use in a mobile user unit in an orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system comprising the steps of:

receiving one or more pilot tone hopping sequences each including pilot tones, said pilot tones each being generated at a prescribed frequency and time instants in a prescribed time-frequency grid; and

in response to said one or more received pilot tone hopping sequences, detecting the received pilot tone hopping sequence having strongest power.

18. The method as defined in claim 17 wherein each of said one or more pilot tone hopping sequences is a Latin Squares based pilot tone hopping sequence.

19. The method as defined in claim 17 wherein said step of receiving yields a baseband version of a received signal and further including a step of generating a fast Fourier transform version of said baseband signal, and wherein said step of detecting is

responsive to said fast Fourier transform version of said baseband signal for determining a received pilot tone sequence having the strongest power.

20. The method as defined in claim 19 wherein said step of receiving further includes a step of quantizing the results of said fast Fourier transform.

21. The method as defined in claim 19 wherein said step of detecting detects a maximum energy.

A3 Cont.

22. The method as defined in claim 21 wherein said step of detecting said maximum energy includes a step of determining a slope and initial frequency shift of pilot tones in a detected pilot tone hopping sequence having the strongest power.

23. The method as defined in claim 22 wherein said step of detecting said maximum energy includes steps of accumulating energy along each possible slope and initial frequency shift of said one or more received pilot tone hopping sequences and generating an accumulated energy signal, in response to said accumulated energy signal, accumulating energy along pilot frequency shifts of said one or more received pilot tone hopping sequences, and in response to an output from said step of frequency shift accumulating, estimating a slope and initial frequency shift of the strongest received pilot tone hopping sequence as a slope and initial frequency shift corresponding to he strongest accumulated energy.

24. The method as defined in claim 23 wherein said accumulated energy is represented by the signal $J_0(s,b_0)$, where $J_0(s,b_0)=\sum_{t=0}^{N_{sy}-1}|Y(t,st+b_0(\mathrm{mod}\,N))|^2$, and s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal, $Y(t,n)$ is the fast Fourier transform data, $t = 0,\ldots, N_{sy}-1$, $n = st+ b_0(\mathrm{mod}\,N)$, and $n = 0,\ldots N\text{-}1$.

25. The method as defined in claim 23 wherein said step of frequency shift accumulating includes a step of accumulating energy along pilot frequency shifts of said one or more received pilot tone hopping sequences in accordance with $J(s,b_0)=\sum_{j=1}^{N_p}J_0(s,b_0+n_j)$, where s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal and n_j are frequency offsets.

26. The method as defined in claim 23 wherein said step of maximum energy detecting includes a step of estimating said slope and initial frequency shift of the strongest received pilot tone hopping sequence in accordance with $\hat{s}, \hat{b}_0 = \arg\max_{s, b_0} J(s, b_0)$, where $\hat{s}$ is the estimate of the slope, $\hat{b}_0$ is the estimate of the initial frequency shift, and where the maximum is taken over $s \in S$ and $b_0 = 0, \ldots, N-1$.

27. The method as defined in claim 22 wherein said step of maximum energy detecting includes a step of estimating at a given time frequency shift of the received pilot tone hopping sequence having strongest energy and estimating a maximum energy value, and in response to said estimated frequency shift and said estimated maximum energy value, generating estimates of an estimated slope and an estimated initial frequency shift of the strongest received pilot signal.

28. The method as defined in claim 27 wherein said estimated frequency shift at time t is obtained in accordance with $n(t) = st + b_0 (\mathrm{mod}\, N)$, where s is the pilot signal slope, t is a symbol time and $n(t)$ is a frequency shift estimate.

29. The method as defined in claim 28 wherein said estimated maximum energy value is obtained in accordance with $[E(t), n(t)] = \max_n \sum_{j=1}^{N_p} | Y(t, n + n_j (\mathrm{mod}\, N)) |^2$, where $E(t)$ is the maximum energy value, $Y(t,n)$ is the fast Fourier transform data, $j = 1, \ldots, N_p$ and n_j are frequency offsets.

30. The method as defined in claim 29 wherein said slope is estimated in accordance with $\hat{s} = \arg\max_{s \in S} \sum_{t=1}^{N_{sy}-1} E(t) \mathbf{1}_{\{n(t) - n(t-1) = s\}}$, where both $n(t)$ and $n(t-1)$ satisfy $n(t) = st + b_0 (\mathrm{mod}\, N)$.

31. The method as defined in claim 29 wherein said frequency shift is estimated in accordance with $\hat{b}_0 = \arg \max_{b_0 = 0, \ldots, N-1} \sum_{t=0}^{N_{sy}-1} E(t) \mathbf{1}_{\{n(t) = st + b_0\}}$.

32. The method as defined in claim 27 wherein said step of maximum energy detecting includes a step of finding the time, $t_0 \in T$, and slope, $s_0 \in S$, such that the set of times t on the line $n(t) = n(t_0) + s_0 (t - t_0)$, has the largest total pilot signal energy.

33. Apparatus for use in a mobile user unit in an orthogonal frequency division multiplexing (OFDM) based spread spectrum multiple access wireless system comprising the steps of:

means for receiving one or more pilot tone hopping sequences each including pilot tones, said pilot tones each being generated at a prescribed frequency and time instants in a prescribed time-frequency grid; and

means, responsive to said one or more received pilot tone hopping sequences, detecting the received pilot tone hopping sequence having strongest power.

34. The invention as defined in claim 33 wherein each of said one or more pilot tone hopping sequences is a Latin Squares based pilot tone hopping sequence.

35. The invention as defined in claim 33 wherein said means for receiving yields a baseband version of a received signal and further including means for generating a fast Fourier transform version of said baseband signal, and wherein said means for detecting is responsive to said fast Fourier transform version of said baseband signal for determining a received pilot tone sequence having the strongest power.

36. The invention as defined in claim 35 wherein said means for generating said fast Fourier transform includes means for quantizing the results of said fast Fourier transform.

37. The invention as defined in claim 35 wherein means for detecting detects a maximum energy.

38. The invention as defined in claim 37 wherein said means for detecting said maximum energy includes means for determining a slope and initial frequency shift of pilot tones in a detected pilot tone hopping sequence having the strongest power.

39. The invention as defined in claim 38 wherein said means for detecting said maximum energy includes means for accumulating energy along each possible slope and initial frequency shift of said one or more received pilot tone hopping sequences, means for generating an accumulated energy signal, means, responsive to said accumulated energy signal, for accumulating energy along pilot frequency shifts of said one or more received pilot tone hopping sequences, and means, responsive to an output from said means for frequency shift accumulating, for estimating a slope and initial frequency shift

of the strongest received pilot tone hopping sequence as a slope and initial frequency shift corresponding to he strongest accumulated energy.

40. The invention as defined in claim 39 wherein said accumulated energy is represented by the signal $J_0(s,b_0)$, where $J_0(s,b_0)=\sum_{t=0}^{N_{sy}-1}|Y(t,st+b_0(\mathrm{mod}\,N))|^2$, and s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal, $Y(t,n)$ is the fast Fourier transform data, $t = 0,\ldots N_{sy}-1$, $n = st+b_0(\mathrm{mod}\,N)$, and $n = 0,\ldots N-1$.

41. The invention as defined in claim 39 wherein said means for frequency shift accumulating includes means for accumulating energy along pilot frequency shifts of said one or more received pilot tone hopping sequences in accordance with $J(s,b_0)=\sum_{j=1}^{N_p}J_0(s,b_0+n_j)$, where s is the slope of the pilot signal, b_0 is an initial frequency shift of the pilot signal and n_j are frequency offsets.

42. The invention as defined in claim 39 wherein said means for maximum energy detecting includes means for estimating said slope and initial frequency shift of the strongest received pilot tone hopping sequence in accordance with $\hat{s},\hat{b}_0=\arg\max_{s,b_0}J(s,b_0)$, where $\hat{s}$ is the estimate of the slope, $\hat{b}_0$ is the estimate of the initial frequency shift, and where the maximum is taken over $s\in S$ and $b_0=0,\ldots,N-1$.

43. The invention as defined in claim 37 wherein said means for maximum energy detecting includes means for estimating at a given time frequency shift of the received pilot tone hopping sequence having strongest energy and for estimating a maximum energy value, and means, responsive to said estimated frequency shift and said estimated maximum energy value, for generating estimates of an estimated slope and an estimated initial frequency shift of the strongest received pilot signal.

44. The invention as defined in claim 43 wherein said estimated frequency shift at time t is obtained in accordance with $n(t)=st+b_0(\mathrm{mod}\,N)$, where s is the pilot signal slope, t is a symbol time and $n(t)$ is a frequency shift estimate.

A3 Cont.

45. The invention as defined in claim 44 wherein said estimated maximum energy value is obtained in accordance with $[E(t),n(t)] = \max_{n} \sum_{j=1}^{N_p} | Y(t,n+n_j(\mathrm{mod}\,N)) |^2$, where *E(t)* is the maximum energy value, *Y(t,n)* is the fast Fourier transform data, $j = 1,\ldots, N_p$ and n_j are frequency offsets.

46. The invention as defined in claim 45 wherein said slope is estimated in accordance with $\hat{s} = \arg\max_{s\in S} \sum_{t=1}^{N_{sy}-1} E(t)1_{\{n(t)-n(t-1)=s\}}$, where both *n(t) and n(t-1)* satisfy $n(t) = st + b_0(\mathrm{mod}\,N)$.

47. The invention as defined in claim 45 wherein said frequency shift is estimated in accordance with $\hat{b}_0 = \arg\max_{b_0=0,\ldots,N-1} \sum_{t=0}^{N_{sy}-1} E(t)\mathbf{1}_{\{n(t)=st+b_0\}}$.

48. The invention as defined in claim 43 wherein said means for detecting maximum energy includes means for finding the time, $t_0 \in T$, and slope, $s_0 \in S$, such that the set of times t on the line $n(t) = n(t_0) + s_0(t - t_0)$, has the largest total pilot signal energy.